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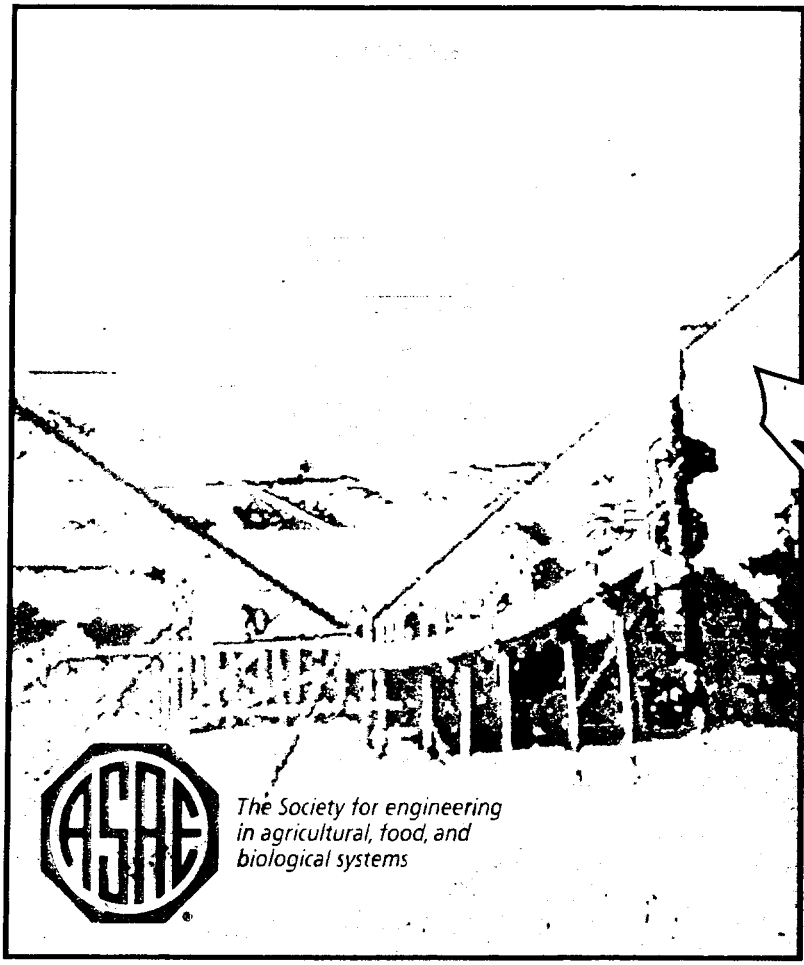

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ROTATING-PLATE SPRINKLER SPACING ON CONTINUOUS-MOVE IRRIGATION LATERALS

Darrell W. DeBoer [1], Micheal J. Monnens [1] and Dennis C. Kincaid [2]

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ABSTRACT

Understanding the operational characteristics of irrigation sprinklers is necessary before irrigation professionals can make sound recommendations regarding the use of sprinkler technologies for field conditions. Results of laboratory studies regarding rotating plate sprinklers are reported. Uniformity of radial water application from individual sprinklers has a major influence on uniformity of water application under a continuous-move irrigation machine. Nozzle pressure can have a significant effect on radial water application patterns, especially when less than recommended pressures are used. Water application patterns are not as sensitive to changes in nozzle diameters as to nozzle pressures. Uniformity of water application can also be very sensitive to sprinkler spacing. The greater the variation in radial water application intensities for individual sprinklers, the more critical proper sprinkler spacing becomes.

Keywords: Sprinkler irrigation, Rotating-plate, Application rate, Application uniformity

INTRODUCTION

Maximizing wetted areas along with a corresponding reduction in water application intensities has been one of the goals of the irrigation sprinkler industry. However, in drop trajectory theory, distance of throw is directly related to drop size, which means one can expect to encounter larger drops when technologies that increase distance of throw are used. Reduced application intensities will cause a reduction in potential surface runoff problems while an increase in wetted area and a corresponding increase in drop mass and velocity (energy) will tend to exacerbate soil sealing and increase surface runoff. It is difficult to predict the impact of increased wetted areas on surface runoff since each field situation is unique and must be considered on its merit.

Before irrigation industry professionals can assess and make recommendations regarding an appropriate sprinkler selection for a given crop and soil scenario, an acceptable procedure based on reliable data and field evaluations must be established. The purpose of this paper is to present some data and findings that are available for the development of such a procedure.

INVESTIGATION DETAILS

Laboratory evaluations of two rotating-plate sprinklers ROTATOR ("R" series) and SPINNER ("S" series) manufactured by the Nelson Manufacturing Co.* (Fig. 1) were conducted at South Dakota State University. Rotating plates for the "R" series sprinklers revolve from 1 to 10 rpm while the "S" series sprinklers revolve from 100 to 600 rpm depending on nozzle discharge and velocity. Spray plates with 4 and 6 grooves were used in the study. Identification of the "R" series sprinkler with a four channel plate is R-4. Designations of R-6, S-4 and S-6 have similar sprinkler and spray plate meanings. Nozzle pressures ranging from 50 to 200 kPa and nozzle diameters of 4.8, 6.4, 7.9 and 9.9 mm were evaluated in the investigation.

Agricultural Engineers, [1] South Dakota State University, PO Box 2120, Brookings, SD 57007 and [2] USDA-ARS, 3793 N 3600 E, Kimberly, ID 83341.

* Mention of commercial products is included for the benefit of the reader and does not imply their endorsement by South Dakota State University or the USDA- Agricultural Research Service.

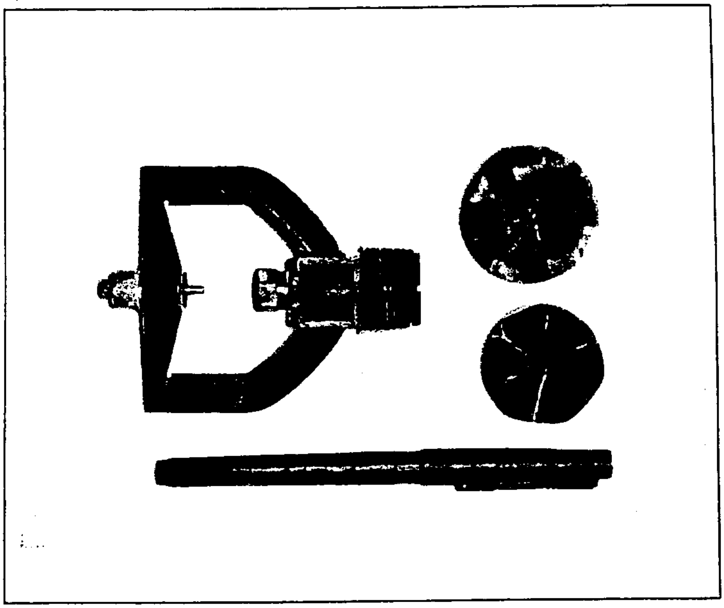

Figure 1. Rotating plate sprinkler with the two spray plates used in the investigation.

The 50 kPa pressure is less than the minimum recommended operating pressure for the R-4, R-6 and S-4 sprinklers and near the minimum recommended pressure for the S-6 sprinkler. A 100 kPa pressure is near the minimum pressure for the R-4 sprinkler, within the recommended range for the R-6 sprinkler and near mid-range of the recommended operating pressures for the S-4 and S-6 sprinklers. The 150 kPa pressure is near mid-range for the R-4 and R-6 sprinklers and near the maximum operating pressure for the S-4 and S-6 sprinklers. Nozzle diameters are representative of manufacturer recommended diameters.

Water application patterns for the sprinklers were measured for a no-wind condition in the laboratory with the sprinklers located 2.5-m above catch containers which were positioned along the sprinkler jet trajectory (Monnens, 2000). Water application uniformities for a continuous-move irrigation lateral were simulated using a single ray, sprinkler application pattern. The single ray pattern was used to develop an application depth grid for a revolving sprinkler; application depth grids were overlapped to account for sprinkler spacing and overlap; and the overlapped application depths were used to calculate total water depths at 0.5-m intervals along the length of a continuous-move lateral. Christiansen's uniformity coefficients (appropriate for a lateral-move system) were determined from the 0.5-m interval values.

FINDINGS

Application Rates and Patterns

ROTATOR sprinklers have larger wetted radii than SPINNER sprinklers for the same nozzle pressure and diameter (Fig. 2). Wetted radii for the ROTATOR sprinklers are about 1 m (12 %) larger than the SPINNER sprinklers for both the 4 and 6-gooved spray plates with a 100 kPa nozzle pressure and 6.4 mm diameter. The 4-grooved spray plate produced only a 0.25 m larger wetted radius than the 6-grooved plate in this instance. However, an inspection of wetted radii for the four sprinklers operating at a 150 kPa pressure with a 7.9 mm nozzle (not shown) indicated about a 1.5 m (20%) wetted radius increase for the ROTATOR sprinklers and a 0.75 m increase for the 4-grooved plate. The magnitudes of radii differences among the sprinklers are not constant but the ROTATORS will have larger wetted radii than the SPINNERS and the 4-grooved plates will have larger values than the 6-grooved plates. In addition, one can expect a larger wetted radius increase for the 4-grooved plate than the 6-grooved plate when ROTATOR sprinklers are used than when SPINNER sprinklers are used. Differences between radii for the SPINNER sprinklers were only about 0.5 m (5%) for the largest nozzle pressures and diameters tested while differences of 15 to 20 % can be expected for the ROTATOR sprinklers.

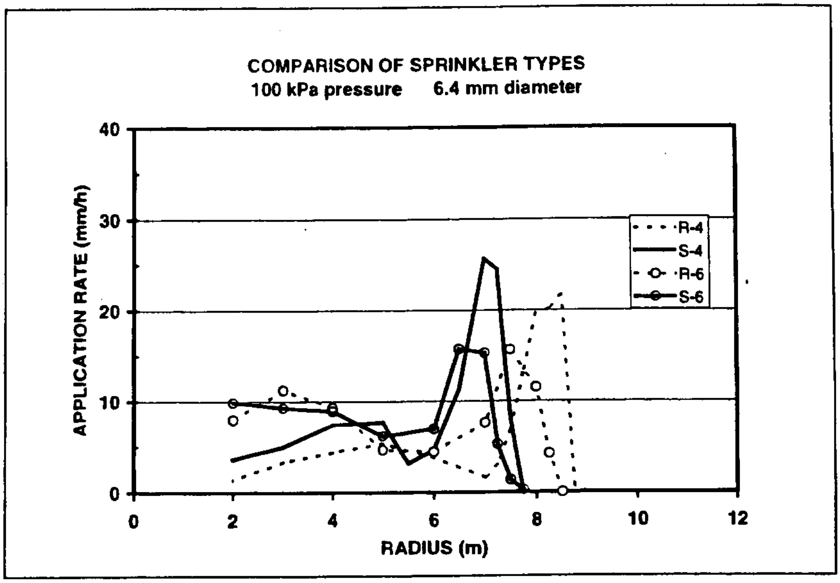

Figure 2. Application patterns for the R-4, S-4, R-6 and S-6 sprinklers at 100 kPa nozzle pressure and 6.4 mm nozzle diameter.

Application rates can have large variations with distance as shown in Fig. 2. All of the sprinklers tend to have relatively uniform rates until the distal 2 m of the wetted pattern where there is a two- to five-fold increase in application rates. This large variation in application rate can have a significant influence on water application uniformity, as discussed later in this paper.

The "spiking" of the application rate intensifies when the sprinklers are operated below recommended pressures (Fig. 3). The minimum recommended operating pressure for this nozzle and sprinkler combination is about 100 kPa. Clearly, the 50 kPa application pattern can be expected to cause severe application uniformity problems. Wetted radii increased from about 6 to 10 m as nozzle pressure increased from 50 to 200 kPa with a small change for the two largest pressures. This small change in wetted radii for the two largest pressures was also found for other nozzle diameters and sprinklers. Satisfactory water distribution patterns occur when sprinklers are operated within recommended operating pressure ranges.

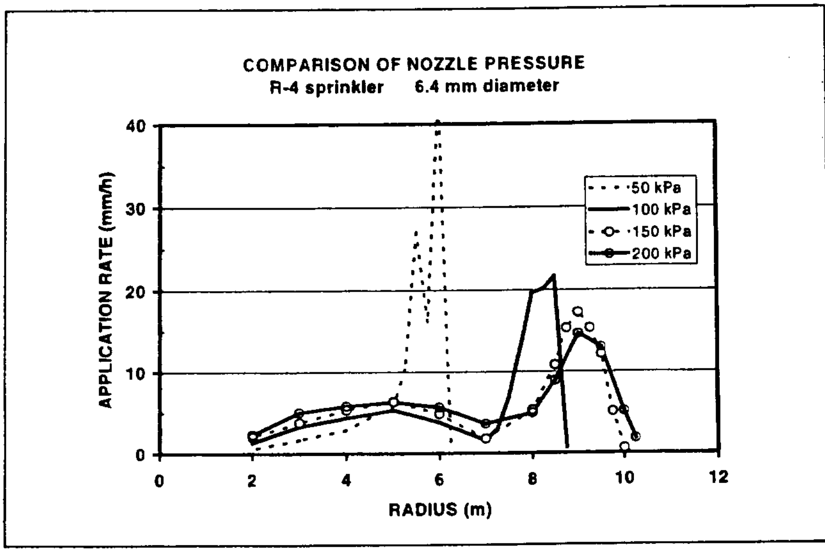

Figure 3. Application patterns for the R-4 sprinkler with a 6.4 mm nozzle diameter at 50, 100, 150 and 200 kPa nozzle pressures.

Changes in nozzle diameters do not produce the large differences in wetted radii and maximum application rates at the distal end of the wetted pattern that nozzle pressure changes do. Maximum application rates at the distal end of the wetted pattern for the ROTATOR sprinkler operating at 150 kPa were about the same for four nozzles ranging from 4.8 to 9.9 mm in diameter (Fig. 4). However, for this case, the wetted pattern tended to be double peaked and large changes in application rates for the inside peak are evident. The interior peak was much greater than the distal peak for the 9.9 mm diameter nozzle. Again, the relative shape of the wetted pattern has an impact on the uniformity of water application.

Position of the sprinkler relative to the top of a crop canopy or soil surface can have a major effect on water application distribution (Fig. 5). The water distribution pattern for the condition where the sprinkler is located 2.5 m above a crop canopy is a familiar one, but lowering the sprinkler to where it is only 0.5 m above the canopy caused the wetted radius to shrink from 10 to about 7.5 m. The double peak is evident for the 0.5 m pattern where both peak application rates are equal to or greater than the single 2.5 m peak rate. Such a double peaked pattern can be a blessing or a curse for water application uniformity and is greatly dependent on sprinkler spacing.

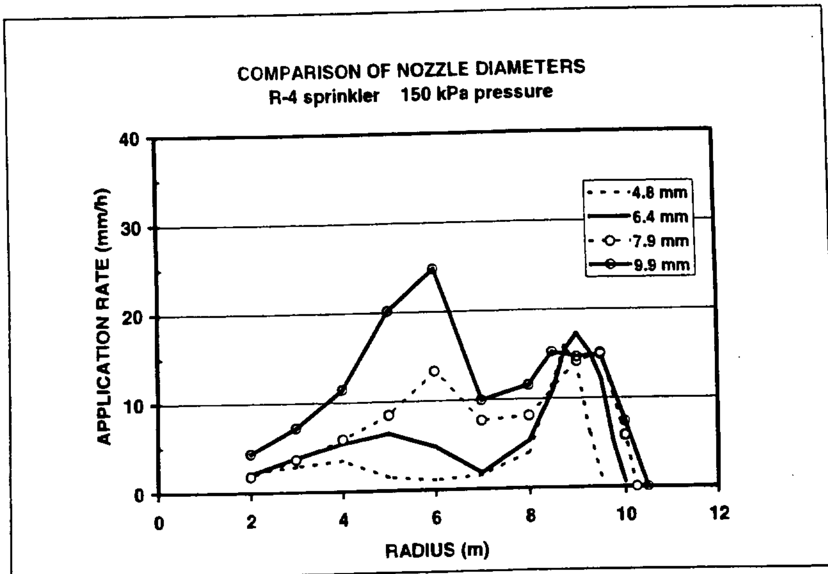

Figure 4. Application patterns for the R-4 sprinkler at 150 kPa nozzle pressure and 4.8, 6.4, 7.9 and 9.9 mm nozzle diameters.

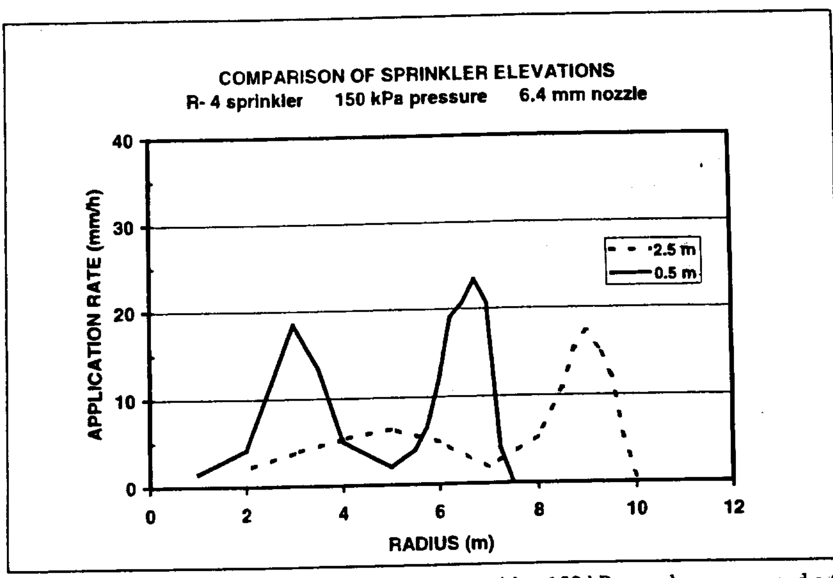

Figure 5. Application patterns for the R-4 sprinkler with a 150 kPa nozzle pressure and a 6.4 mm nozzle diameter for 0.5 and 2.5 m sprinkler elevations.

Application Uniformities

Sprinkler spacing can have a big influence on water application uniformities, especially for application patterns that contain large variations in application rates. Calculated uniformity coefficients (UC) for a ROTATOR sprinkler with a 4-grooved plate, 6.4 mm nozzle diameter and 100 kPa pressure are illustrated in Fig. 6 for sprinkler spacings ranging from 2 to 7 m. The water application pattern for this sprinkler with a wetted radius of about 9 m is shown in Figs. 2 and 3. A maximum UC of 93 % occurred for the smallest sprinkler spacing of 2 m. Uniformity values continued to decrease with an increase in sprinkler spacing to 5 m when the lowest UC value of 80 % occurred. Then an increase in spacing to 6 m caused the UC to increase to 89 % followed by a decrease to 80 % for the 7 m spacing. The large variation in UC values for a small change in sprinkler spacing is caused by the high application rate near the distal end of the wetted pattern as compared to rates for other portions of the wetted pattern. Kincaid et al. (2000) indicated that excellent uniformities can be obtained when sprinkler spacings do not exceed 50 % of the wetted radius, which is confirmed by these results.

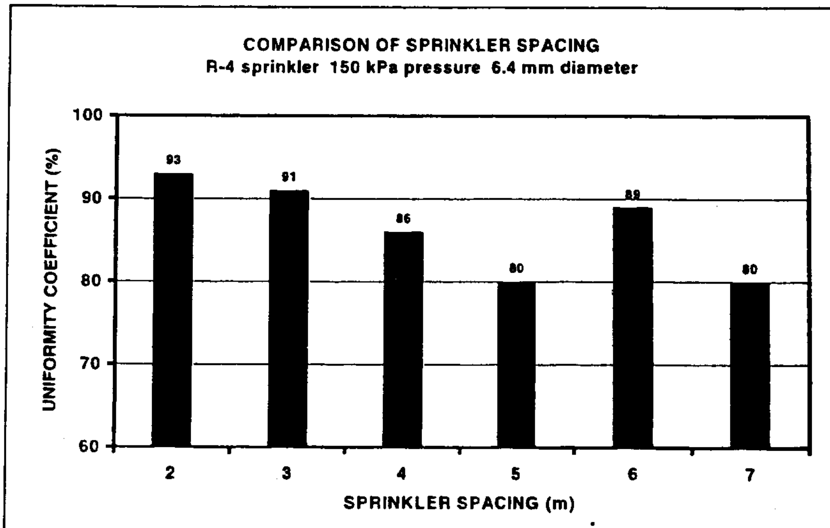

Figure 6. Uniformity coefficients for the R-4 sprinkler with a 150 kPa nozzle pressure and a 6.4 mm nozzle diameter for 2 to 7 m sprinkler spacings.

UC values for the water application distributions as influenced by nozzle pressure (Fig. 3) are presented in Fig. 7. The 200 kPa pressure produced the most uniform water application pattern and also the highest UC values of 90 % or more for all spacings except for the 6 m spacing, while the extremely spiked pattern for the 50 kPa pressure had excellent UC values for the 2, 3 and 4 m spacings but had the lowest UC values of 68 and 70 % for the 5 and 7 m spacings. The 150 kPa pressure UC values were similar to but slightly smaller than the 200 kPa values.

Again, the impact of water distribution patterns as related to changes in nozzle diameters (Fig. 4) is shown in Fig. 8. UC values, ranging from 91 to 100 % (rounded to the nearest integer value), were the highest and least influenced by sprinkler spacing for the pattern with the smallest changes in application rates (9.9-mm nozzle diameter). The 4.8 mm water distribution produced the largest variations in UC values with a low value of 79 % for the 5 m sprinkler spacing.

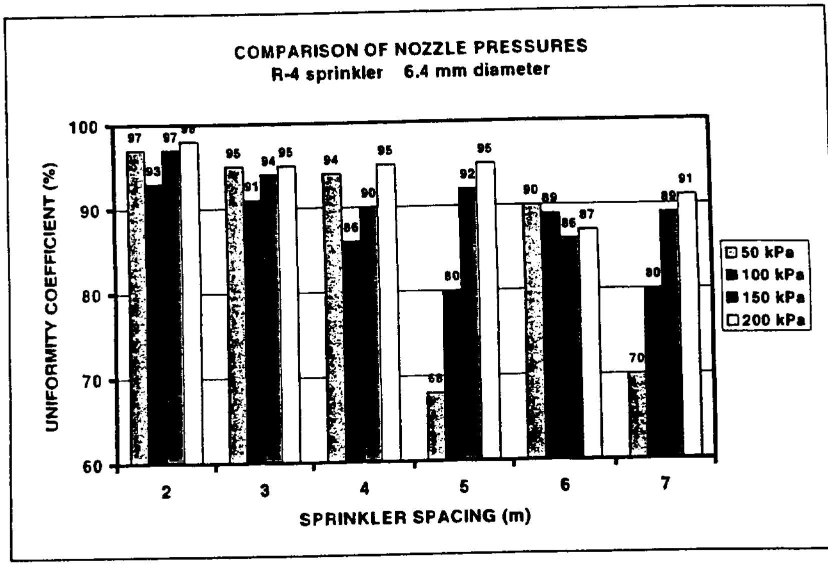

Figure 7. Uniformity coefficients for the R-4 sprinkler with a 6.4 mm nozzle diameter and 50, 100, 150 and 200 kPa nozzle pressures for 2 to 7 m sprinkler spacings.

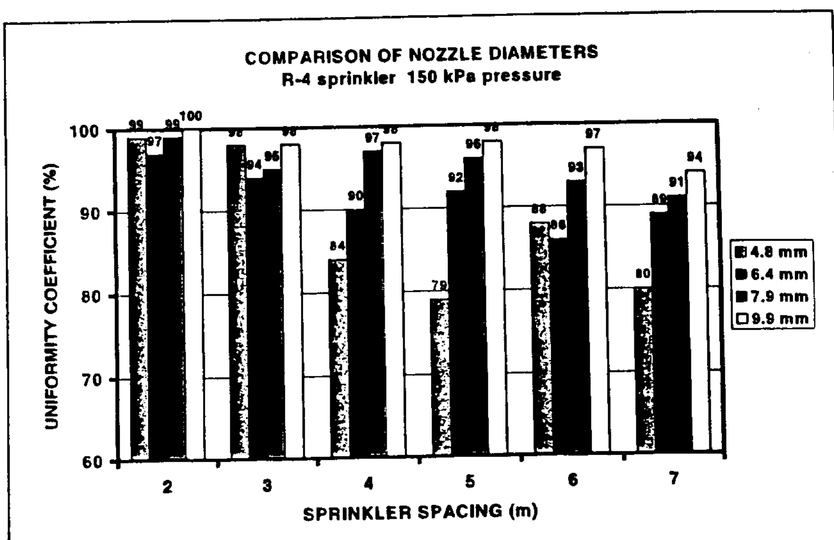

Figure 8. Uniformity coefficients for the R-4 sprinkler with a 150 kPa nozzle pressure and 4.8, 6.4 and 7.9 mm nozzle diameters for 2 to 7 m sprinkler spacings.

The double peaked application pattern (Fig. 5) associated with the 0.5 m sprinkler elevation produced some interesting UC values (Fig. 9). Values of 99 and 97 % were found for the 2 and 7 m spacings, respectively, while the 4 and 6 m spacings had values of about 80 %. When water application patterns overlap in a manner where the peak rate of one pattern is aligned with the position of the valley of an adjacent sprinkler pattern, excellent UC values can be produced as was the case for the 7 m spacing. When peak rates tend to coincide, lower UC values can be expected, as is the case for the 4 m spacing.

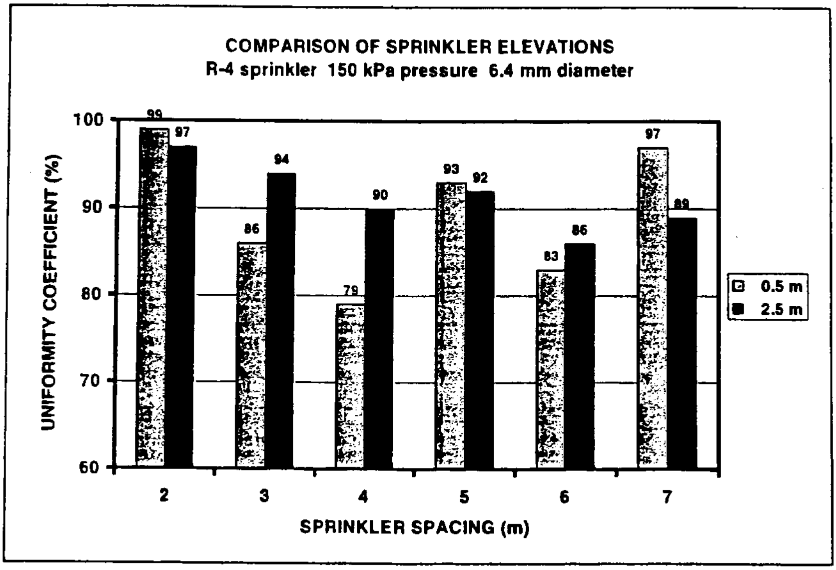

Figure 9. Uniformity coefficients for the R-4 sprinkler with a 150 kPa nozzle pressure, a 6.4 mm nozzle diameter and 0.5 and 2.5 m sprinkler elevations for 2 to 7 m sprinkler spacings.

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